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Naval Aerospace Medical Research Laboratory
Pensacola, Florida

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13. ABSTRACT

Field patterns were measured for the first time in proximity to human subjects exposed to low intensity cw microwave fields at 1 GHz. Pronounced standing waves were observed on the illuminated side and distinct shadows produced on the opposite side of the subjects. The fine structure of the interference patterns was related to the polarization of the incident wave.

The field perturbations described have implications in evaluation of the radiation dose experienced by one man in proximity to another, in the location of personal dosimeters, and in the estimation of energy absorbed by man from a microwave field.

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SUMMARY PAGE

THE PROBLEM

A definite need exists for further information concerning the biological effects of low intensity microwave radiation on man. As part of an extensive investigation of these effects a study in progress is concerned with the direct measurement of the microwave energy reflected, diffracted and transmitted by man.

FINDINGS

Energy density patterns were determined in proximity to human participants introduced into horizontally or vertically polarized microwave fields of low intensity ($<50 \mu W/cm^2$) at 1 GHz. A standing wave was formed in space on the illuminated side and a pronounced shadow on the opposite side. Characteristics of the interference pattern are related to the polarization of the incident wave.

ACKNOWLEDGMENTS

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INTRODUCTION

Considerable progress has been made in evaluation of the biological effects and hazards of microwave radiation; however, general agreement has been reached only in the case of exposure to fields of high power where the effects are clearly thermal. No such unanimity of opinion exists where low-power fields are concerned.

An investigation is in progress at this laboratory to characterize the effects of low intensity microwave radiation on man, to evaluate their significance in terms of health and performance and, when possible, to further understand the basic interaction between microwave energy and man. Central to the rationale of this study is the concept that unequivocal conclusions regarding the effects of low intensity microwave radiation on man can best be expected from studies in which man himself serves as the experimental subject.

Concomitant with this investigation was a study of the reflection and diffraction of microwave energy by human participants immersed in carefully defined, low intensity fields of different frequencies and polarizations. This study provided a quantitative representation of the spatial energy distribution in proximity to man as a function of the parameters of radiation. This information may provide the basis for a non-invasive method of estimating the energy actually absorbed by man from a microwave field.

METHOD AND PROCEDURE

The facility used in the present study was a microwave range designed specifically for the study of the physiological and psychological effects on man of low intensity microwave irradiation. Several contemporary concepts were incorporated in the system design to provide maximum versatility and, as a consequence, short- and long-term studies can now be made that were not previously possible. Only the more salient of these concepts are mentioned here--a more detailed description of the facility will appear elsewhere.

A modification of the "compact range technique" (1) was used to achieve the desired spatial power distribution throughout an indoor experimental chamber. A large parabolic reflector (4.8 meters in diameter) fed by linearly polarized, rotatable feed horns, collimated and polarized the beam illuminating an absorber wall 5.6 meters from the reflector. The experimental chamber was situated between a 2.5m x 2.5m aperture in the absorber wall and an absorber backpanel located 2.5m behind the wall. The absorber wall, aperture and absorber backpanel were coaxial with, and normal to, the beam axis. This arrangement provided adjacent shielded areas above, below and at both sides of an illuminated experimental volume of approximately $15m^3$. The shielded areas contained instrumentation and test apparatus that by necessity were located close to the subject. Figure 1 indicates the relationships of the major range components and defines the coordinate system used in descriptions of the field.

The RF power sources consisted of either one or two microwave sweepers that drove four traveling-wave tube (TWT) amplifier chains to provide radiation at any frequency from 1 to 12.4 Gigahertz (GHz). Frequency was continuously monitored by a highly

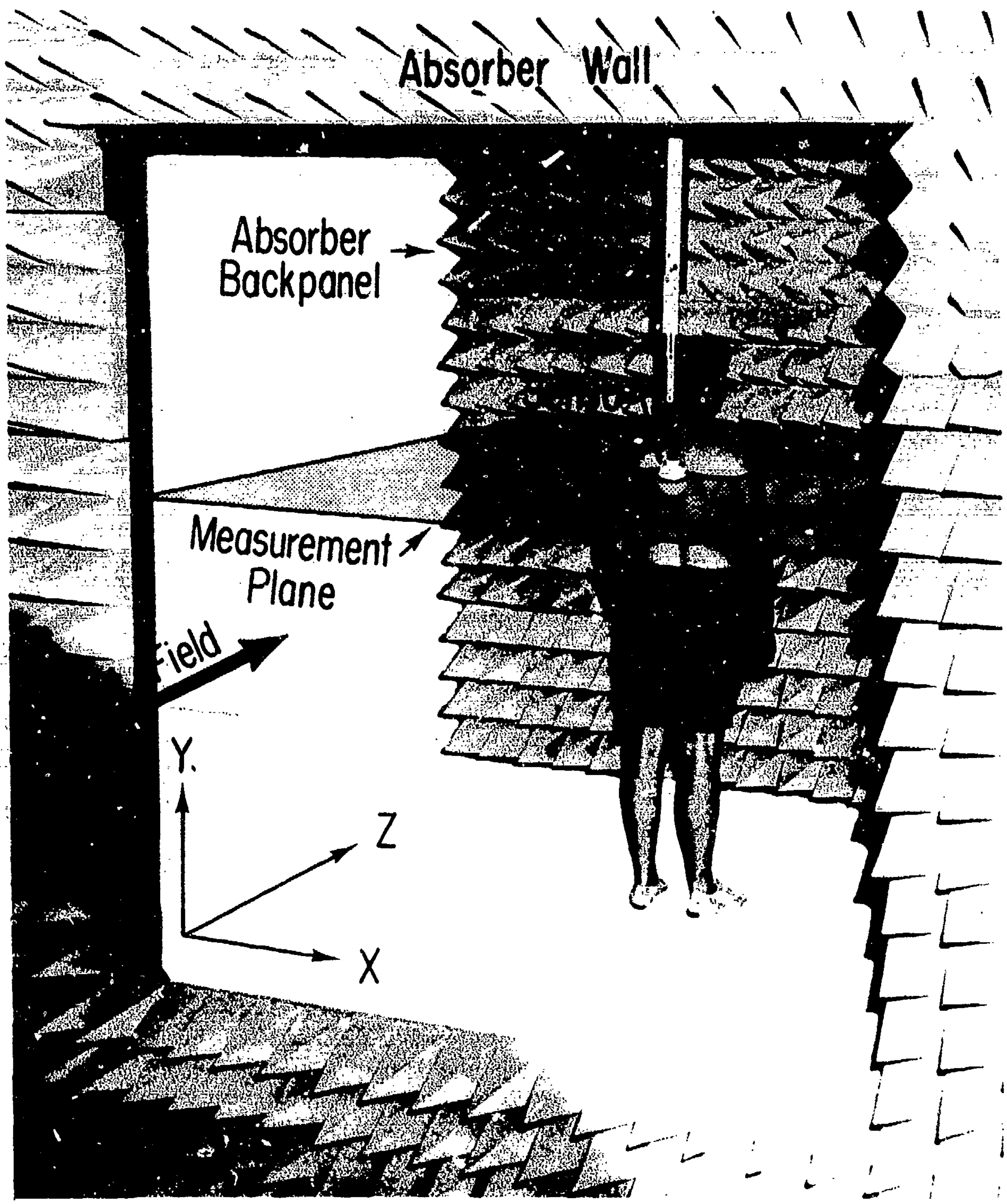

Figure 1

Human Subject in Position for Microwave Reflection, Diffraction and Transmission Measurements

accurate, crystal-controlled counter. The source could be either amplitude or frequency modulated, and operated in either the continuous wave (cw), pulsed or swept frequency mode. Changes in frequency or power could be programmed at any desired rate on an external programmer. Monochromatic radiation was assured during single-frequency experiments by filtering. The broad range of wavelengths permitted frequency-scaling experiments with animals and models in which the ratio of wavelength to subject size could be varied.

One of the essential requirements of the present study was accurate power measurements. These measurements were based upon recent concepts (2) and instrumentation developed and provided by the National Bureau of Standards. Three orthogonal dipoles were combined to form a very small isotropic sensor capable of measuring complicated microwave fields with a high degree of spatial resolution. The high sensitivity of the instrument permitted accurate measurement of very low power levels of radiation. The sensor was mounted at the end of an arm supported by an overhead gantry that drove in either of two orthogonal directions (X or Z) in a horizontal plane. The elevation of this plane was selected by adjusting the length of the arm (Figure 1). Analog voltages were provided from the drive system to indicate the sensor position and from the sensor to indicate the field amplitude. Plots of these data demonstrated the spatial power density distribution through the experimental chamber.

The participant was illuminated by vertically or horizontally polarized cw radiation at a frequency of 1 GHz as he stood at the center of the chamber between the aperture and the absorber backpanel. Maximum intensity of the incident wave was approximately $50 \mu W/cm^2$. Successive scans of the field were made on the X-axis at increasing distances from the participant on an X-Z plane located at chest height (Figure 1). The results of the individual scans were subsequently offset on the X-axis and redrawn to provide a three-dimensional view of the patterns of energy distribution with and without the participant in the field (A and B in Figure 2; A and B in Figure 3). Some of the fine structure of the field is indicated by expansion of the Z-axes.

RESULTS AND DISCUSSION

Field perturbations in proximity to man may be readily visualized by comparison of the spatial power density of the unperturbed field in the absence of man with that following his introduction into the field. Results shown in Figures 2 and 3 were found in measurements with a participant of average size and physique and similar results were noted with two other participants. Such local field perturbations caused by man in a microwave field have not been previously demonstrated.

Essentially similar interference patterns were obtained with either vertical or horizontal polarization of the incident wave. In both cases the radiation formed a standing wave in space on the illuminated side of man and pronounced shadows extending to a considerable distance on the opposite side. It can be seen that field intensities in the vicinity of man may vary from zero to as much as three times the incident value. There were differences in the patterns, however, that were related to the polarization of the

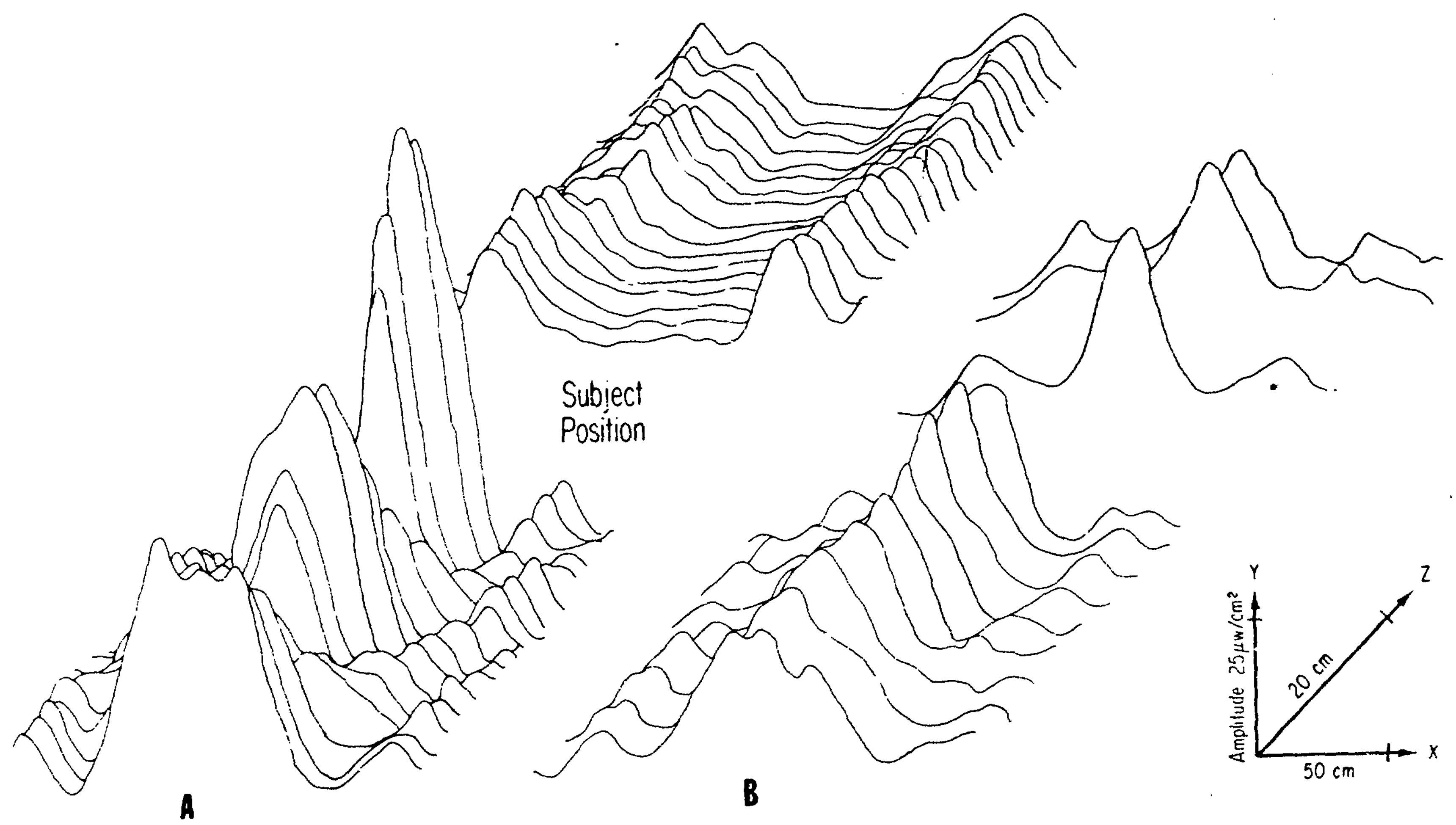

Figure 2

Microwave Field Pattern – 1 GHz Vertical Polarization
(A) With human subject (B) Without subject

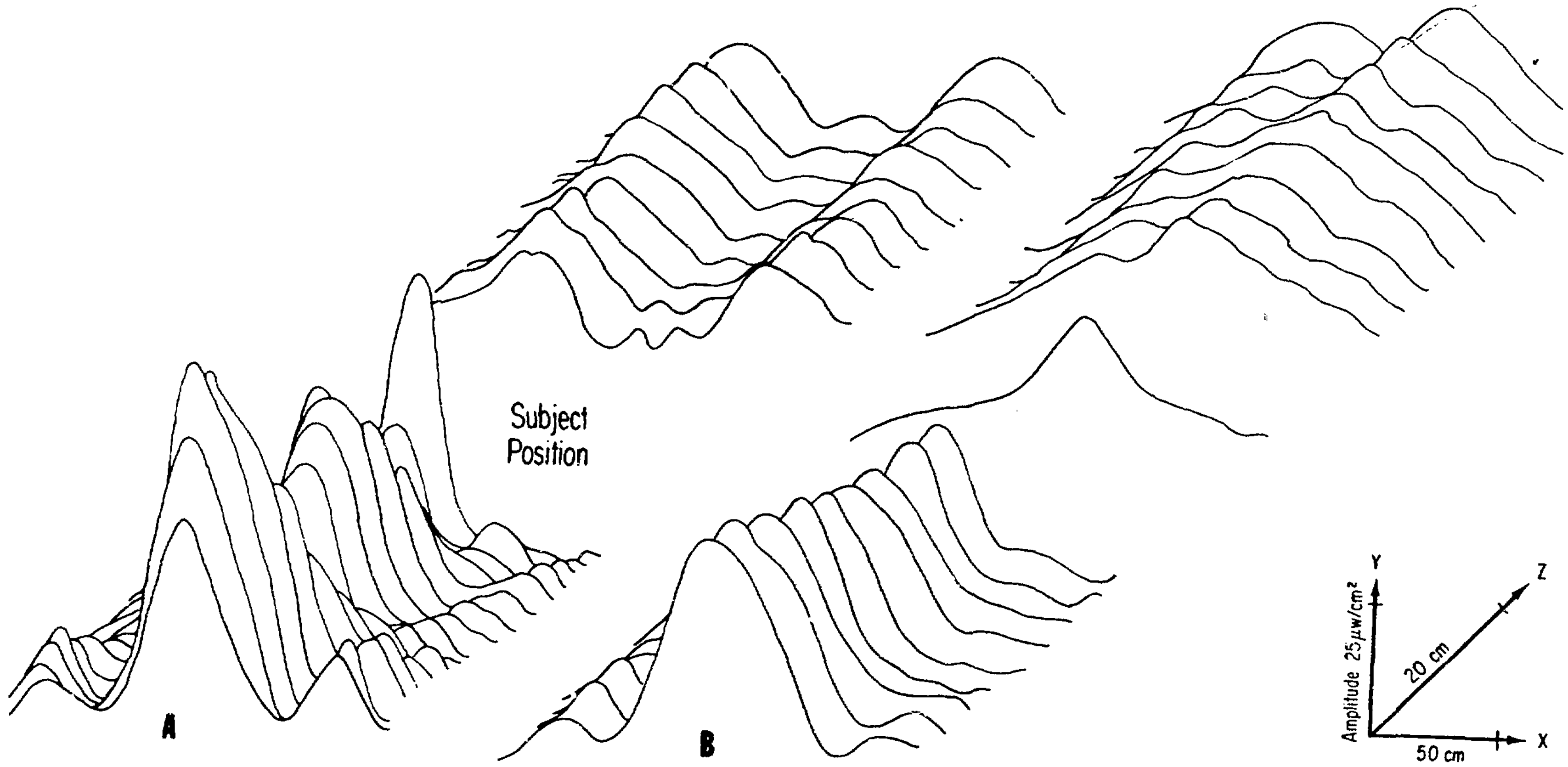

Figure 3

Microwave Field Pattern - 1 GHz Horizontal Polarization
(A) With human subject (B) Without subject

incident wave. The most apparent of these occurred in the diffraction patterns seen in the shadow areas. The shadow was broad and well-defined where the incident electric field was parallel to the long axis of the body (A in Figure 2), while an electric field perpendicular to the body axis produced a more narrow shadow with diffuse boundaries (A in Figure 3).

It is apparent that one man can considerably modify the microwave field incident on his neighbor. These observations place restrictions on the proximity of several subjects exposed at the same time to a microwave field for observations of biological effects. Similar considerations extend to the approach of an observer and to the location of experimental apparatus adjacent to the subject. It appears desirable to locate such equipment in the microwave shadow of man to experience the least disturbance either on or by the equipment.

The characteristic reflection and diffraction patterns observed around man invite considerations and speculations which have not been tested experimentally. It is apparent that power measurements made in the proximity of man for the purpose of safety monitoring may be subject to misinterpretation if the standing waves and shadows are not taken into account. Placement of a personal microwave dosimeter on the garment of a person may position it at the first peak of the standing wave at certain frequencies giving an improper reading of the power to which the person is actually exposed. The positioning of the dosimeter is therefore frequency dependent. It is evident that a careful appraisal of the significance of the values of personal dosimeter readings should precede application in safety monitoring.

Another consideration concerns the use of the standing wave for measurement of the reflected power and, with the incident and transmitted power known, of the power absorbed by man. It is expected that these studies will provide the basis for a new and less ambiguous method of estimating the energy absorption by man from a microwave field. It may even be possible to determine the absorption of specific tissue layers.

Both the spatial standing wave and the radial diffraction field in proximity to man resemble the field patterns demonstrated theoretically and experimentally to occur around a conducting circular cylinder (3). Studies in progress with conducting and dielectric cylinders will explore these similarities in greater detail. The results of such studies should make it possible to relate the local interference patterns produced by man to those extensively studied for inanimate objects of less complex composition and shape. If this relationship can be established, access will be provided to a much wider theoretical and experimental data base against which to compare the results of human research.

By far the most important and unique advantage of the approach presented in this report is that the exquisitely complex and dynamic nature of the living human organism is automatically taken into account in the proper perspective. Direct measurement of the reflection and transmission of microwave energy by human subjects will provide information concerning the interaction of man with a microwave environment that can be obtained in no other way.

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